

A Miniature 5.5 Amp DC Motor Drive

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Abstract- This paper details the design process and the stages of construction of a 12V 5.5A DC motor drive on a very small 1.5 inches by 1.5 inches printed circuit board. The relatively small-size but high power dc motor drive may open door to a wide spectrum of industrial electronic applications. The tiny size was made possible by the latest technology in power electronics for integrated dc motor drive technology and was aimed to improve overall efficiency of the dc motor drive circuit. A laboratory prototype was built and loading tests and measurements were conducted. The results of these tests and measurements will also be presented in this paper.

I. INTRODUCTION

Precise motor speed and directional control is essential to industrial manufacturing today. In order to attain meticulous motor speed and directional control, 'drives' are often used. This paper chronicles the creation of a miniature DC motor control drive including details on the stages of design, construction, and testing. A basis of power-electronics is its use of relatively high power rated components within circuits that are configured for high efficiency and minimum power loss. The aforementioned circuits have traditionally been much larger in size than conventional electronics which often sacrifice power efficiency to minimize size. Recent technological advances, however, have allowed power electronics components to continue to reduce in size while still maintaining their high efficiency. One of the main purposes of the project described in this paper was to demonstrate the minimal size that can be attained within a multifunctional, efficient, and precise motor control drive which utilizes power electronics. After researching potential drive design philosophies, a drive circuit described in [1] was chosen. The circuit offers several useful features such as numerous protection schemes in a small and cost-effective package. Examples of these appealing features are over-current protection, over-temperature shutdown, soft-start capability, under-voltage lockout, and over-voltage protection [1]. Furthermore, the drive circuitry is comprised of power electronics' components such as high frequency switching power MOSFETs and utilizes power-electronics' techniques such as Pulse Width Modulation (PWM) [1]. Although reference [1] explains well the features of the chip used for the drive, however it is lacking laboratory test data to show the operation and characteristic of the final dc drive circuit. Therefore, another objective of the project as presented in this paper was to build a lab prototype and then conduct tests and measurements which would be useful to learn about the operation of this small-size dc drive.

II. DESIGN

A. Schematic Capture

After settling on the basic circuit design, the specific schematic design was completed using OrCAD Schematic Capture 9.1. To minimize the size of the circuit surface-mount (SMD) components should be used wherever possible. For instances, SMD capacitors and resistors used are of package size 1206, the thick film resistors are .126 inches long and .061 inches wide with a 5% tolerance [2]. However, other components such as headers are through-hole terminals due to the difficulties in obtaining high current rated headers. Considering the terminal blocks within the schematic design, 3 headers were used for ease of routing and to maximize the routing efficiency of a double-sided, single-layer board. Moreover, the power and ground were separated on the board by placing them on independent terminal blocks. Figure 1 shows the final schematic of the dc motor drive circuit.

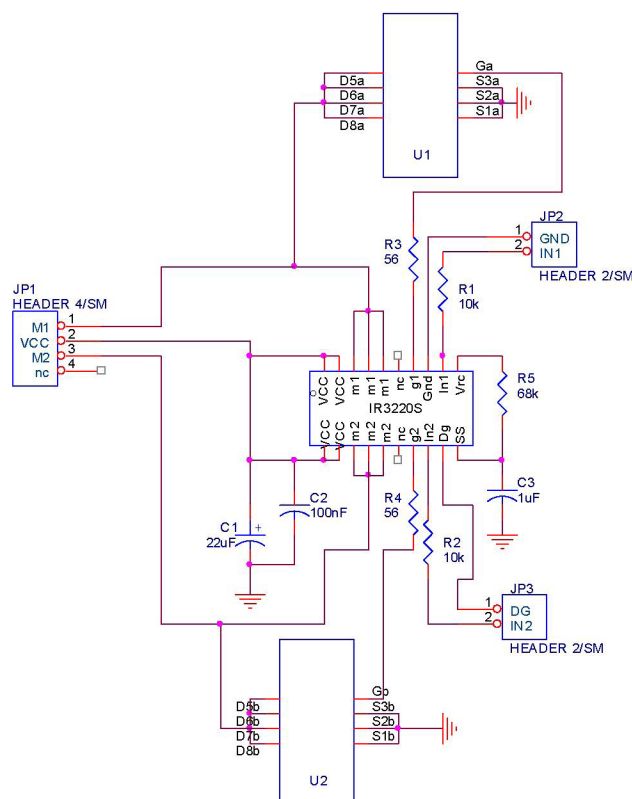


Figure 1. Motor drive circuit schematic

B. PCB Layout

Once the schematic was created, it was then converted to the physical layout of a printed circuit board (PCB), by using OrCAD Layout 9.1. One part of the layout process involves setting the minimum and maximum trace width. This can be done using a resistivity calculation; however, since the PCB consisted of both high current and high frequency signals, an online PCB trace width calculator [3] and National Semiconductors "Layout Guidelines for Switching Power Supplies" [4] were utilized to set my minimum trace width to 60 mils for a 5.5 A rated current draw. In addition to providing guidelines for trace width, reference [3] cautions to maximize the distance between high and low frequency signals and between power and ground leads which were also done on the final PCB.

C. Component Selections

Determining the values, tolerances and ratings of circuit components used in the dc motor drive circuit were performed based on the design calculations and information provided in both [1] and [5]. Once calculations were completed, components were then acquired in the smallest size and most economical way possible. Figure 2 illustrates the PCB after it was manufactured.

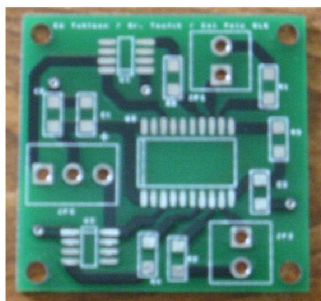


Figure 2. Final manufactured PCB

III. CONSTRUCTION

Discrete components were manually soldered to the board and tested. The final revision of the PCB is 1.5 inches by 1.5 inches. That size could have actually been reduced to about 1.2 inches per side, but the slightly bigger size was chosen to provide ample distance between signal and ground traces and between high and low frequency traces. One additional note on the size of this board: If this was a mass produced item, the PCB size can further be reduced by utilizing a multi-layer board and a copper pour and ground plane. Figure 3 illustrates the PCB after manual soldering of its discrete components.

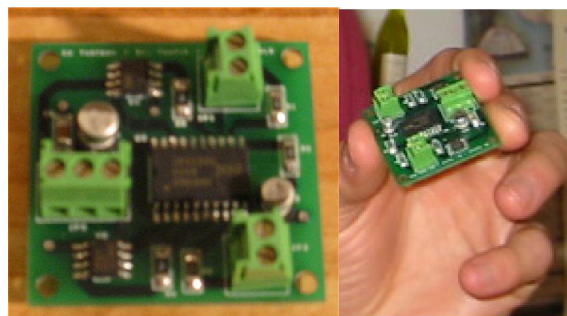


Figure 3. PCB with Soldered Discrete Components

The basis of this drive circuitry is an H-bridge controller design, employing four MOSFETs and a DC motor rated at a maximum of 5.45 amps. The primary function of the drive will be to provide directional or speed control to the motor. The drive circuitry chosen is manufactured by International Rectifier whose part number is IR3220s.

As explained in [5], there are many prominent protective features found within the IR3220s. In addition to its protective features, the IR3220s controls the operation of its internal high-side MOSFETs, and using PWM (pulse width modulation) it controls the cycling of the external low-side MOSFETs [6]. The H-bridge design allows for high functionality, while the thermal design of the IR3220s in tandem with the IR7484 eliminates the need for heat sinks and allows continuous operation at about 6 Amps. One of the drives most important features is its soft start sequence. During a soft-start the drive limits starting current by comparing the PWM signal at the soft-start block to a 3V symmetrical saw tooth wave. This way the switching waveform goes from 0% to 100% duty cycle, offering a low-stress ramp up to its load" [1].

IV. TESTING AND RESULTS

The testing of this project was completed in several phases. First, no load tests were conducted. Second, an apparatus was developed to complete full load tests utilizing a dynamometer (torque speed tester). Full load testing was then conducted wherein rated torque was calculated to be .625 in-lb. In addition, load dynamic testing was also performed. Figure 4 shows the lab setup for conducting the test. The soft-start sequence was observed to work well, as the maximum starting current for 15 starts was only 5.45 Amps. The measured torque-speed relationship is shown in figure 5 which shows that it is in general a linear relationship, and speed was inversely proportional to torque.

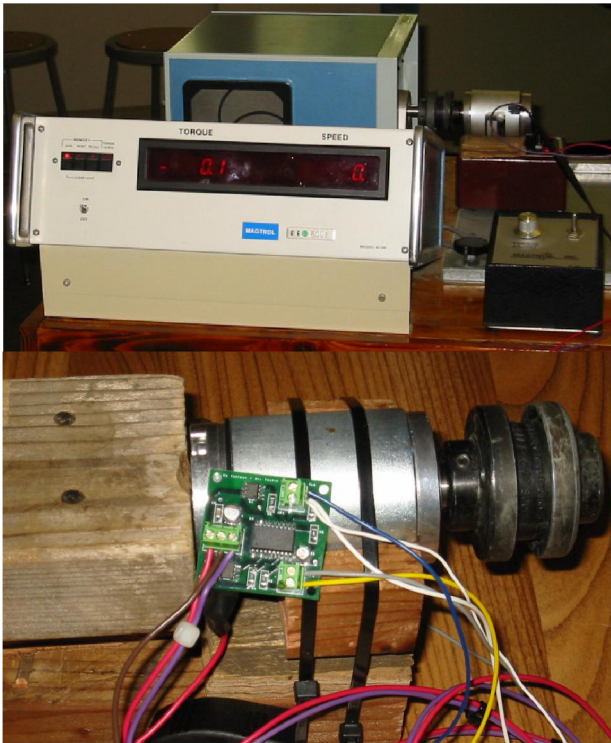


Figure 4. Lab setup for the motor drive test and measurement

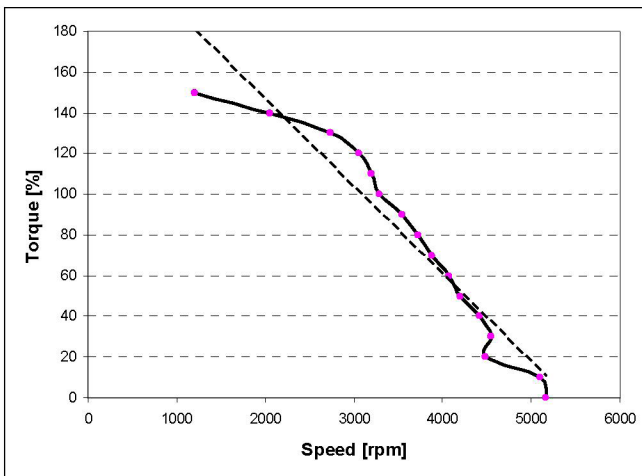


Figure 5. Torque-Speed measurement

Figure 6 illustrates the peak to peak ripple of the output of the dc drive at full load. As shown the ripple is about 10 mV. This translates to 0.083% peak to peak ripple. Figures 7, 8 and 9 show the pwm output from the controller at no load, 50% load and full load respectively. As seen from these figures the pwm outputs maintain their stability at different load conditions. Finally, dynamic loading test was also performed where the load is suddenly changed from 10% to 90% and vice versa. It was then observed that in both cases, the motor drive maintains its output voltage stability or speed stability.

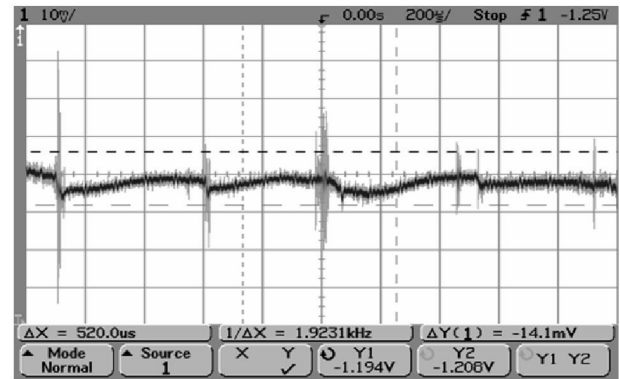


Figure 6. Ripple voltage of the output of the DC drive

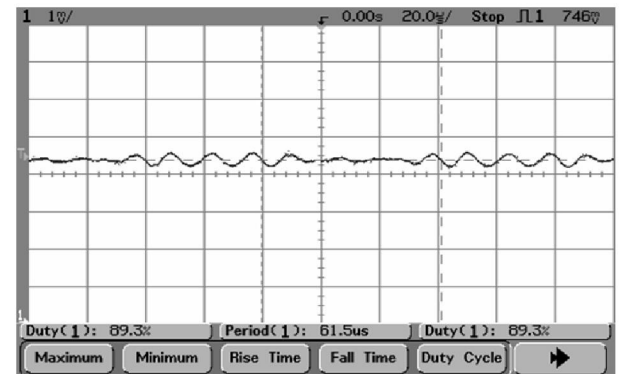


Figure 7. PWM output at no load

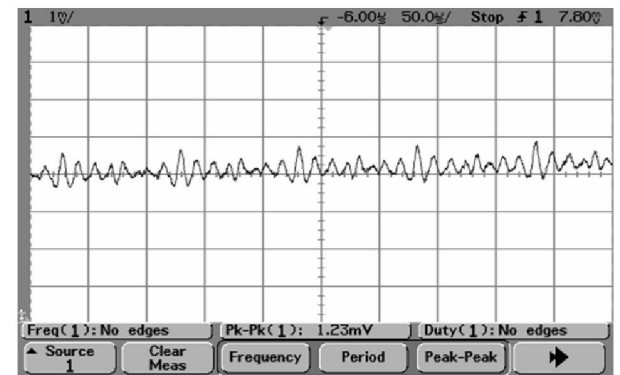


Figure 8. PWM output at 50% load

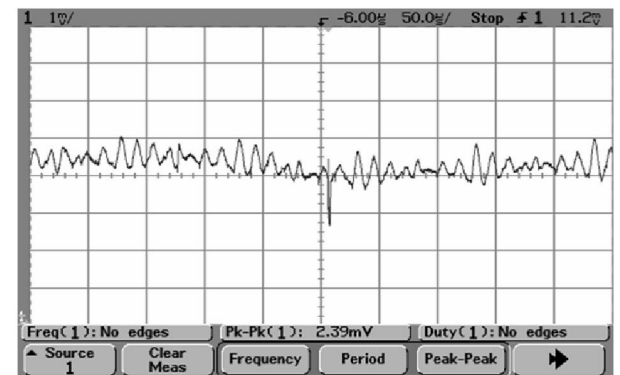


Figure 9. PWM output at 100% load

V. CONCLUSIONS

When motor applications call for a compact but yet relatively high power, then the small-size dc motor drive discussed in this paper will be particularly useful. One example would be motor drive for garage door or gate opener/closer. The design, construction, and testing of the miniature dc drive were presented in this paper. The results show the very good quality of the pwm output at various loading conditions. It is hoped that the miniature dc drive presented in this paper provides a prime example of how power electronics' devices continue to shrink in size, while still providing the high efficiencies that conventional electronics lack.

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